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Resonance in Transmission Work.

BY DONALD H. FRY.

IN an alternating circuit where the electromotive force does not follow a sinusoid, it can always be resolved into a number of component sinusoids, consisting of a fundamental of the same frequency and a number of harmonics, as expressed by the special form of Fourier's theorem:

$$e = a_1 \sin \phi + b \sin 3\phi + c \sin 5\phi + \text{etc.} + a \cos \phi + b^1 \cos 3\phi + c^1 \cos 5\phi + \text{etc.} \quad (1)$$

These sinusoidal components may be calculated, and their effects on the circuit, to some extent, may be separately estimated.

Only the odd harmonics (the third, fifth, etc.) need be looked for, no matter how distorted the curve, since in alternating currents the successive loops are always similar, and an even harmonic would make the successive loops — that is, the positive and negative loops — dissimilar. Neither the generator, the line, the motors — induction or synchronous — nor the transformers, tend to introduce even harmonics, and if artificially introduced, all the iron in the circuit would tend to eliminate them.

In practice, the only harmonics that, as a rule, are of sufficient amplitude to affect the circuit to such a degree as to be of practical consideration, are the third and fifth. Of course there are exceptions to this rule.

The usual method of determining these harmonics from a plotted curve is a slow and laborious procedure, and the object of this article is to give a simpler and more expedient way — one which does not require the use of sine tables. It is usual to divide the tangent of one loop of the plotted curve into a number of equal divisions — $n + 1$. Then there will be n points between $\phi = 0$ and $\phi = \pi$. The abscissa of these points will be

$$\triangle \phi = \frac{\pi}{n+1}, \; 2 \triangle \phi = \frac{2\pi}{n+1} \text{ etc.;}$$

or in general the abscissa may be denoted by

$$k \triangle \phi = \frac{k\pi}{n+1} \quad \text{and its ordinate by } e_k.$$

From (1) we have

$$e_k = a_1 \sin \frac{k\pi}{n+1} + a_3 \sin 3\frac{k\pi}{n+1} + \text{etc.} + b_1 \cos \frac{k\pi}{n+1} + b_3 \cos 3\frac{k\pi}{n+1} + \text{etc.} \quad (2)$$

and by giving k successive values from 1 to n, the values of $a_1\ a_3\ a_5$, etc., $b_1\ b_3\ b_5$, etc., can be determined algebraically from the n equations so found.

Using x as a general subscript, we have

$$a_x = \frac{2}{n+1} \sum_{k=1}^{k=n} e \sin\left(x \frac{k\pi}{n+1}\right)$$

$$b_x = \frac{2}{n+1} \sum_{k=1}^{k=n} e \cos\left(x \frac{k\pi}{n+1}\right) \quad (3)$$

If we make the number of divisions of the tangent of the curve $n + 1$ equal to twice any desired harmonic, then equation (3) is simplified to

$$a_x = \frac{1}{x} \sum_{k=1}^{k=2x-1} e \sin \frac{k\pi}{2}$$

$$\text{and} \quad b_x = \frac{1}{x} \sum_{k=1}^{k=2x-1} e \cos \frac{k\pi}{2} \quad (4)$$

which expanded gives

$$a_x = \frac{1}{x}\left[e_1 \sin \frac{\pi}{2} + e_2 \sin \frac{2\pi}{2} + e_3 \sin \frac{3\pi}{2} + \text{etc.}\right]$$

$$\text{or,} \quad a_x = \frac{1}{x}\left(e_1 - e_3 + \ldots\ldots + e_{2x-1}\right) \quad (5)$$

and likewise

$$b_x = \frac{1}{x}\left(-e_2 + e_4 - \ldots\ldots + e_{2x-2}\right) \quad (6)$$

Figure 1 shows the base of a curve divided into six equal divisions. a_3, or the amplitude of that component of the third harmonic which is in phase with the principle, is

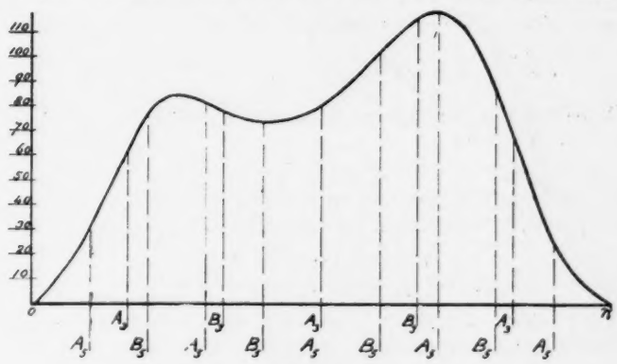


FIGURE 1.

$$a_3 = \tfrac{1}{3}(e_1 - e_3 + e_5)$$
$$= \tfrac{1}{3}(60.8 - 82.8 + 65.2)$$
$$\text{or,} \quad a_3 = 14.4$$

The component differing in phase by 90° is

$$b_3 = \tfrac{1}{3}(-e_2 + e_4)$$
$$= \tfrac{1}{3}(-79.7 + 116.3)$$
$$\text{or,} \quad b_3 = 12.2$$

The lower scale of Figure 1 shows the subdivision in obtaining the fifth.

That it is permissible to neglect the even and the odd ordinates in (5) and (6) respectively is easily proved. For from (2) we have

$$e_1 = a_1 \sin \frac{\pi}{2x} + a_3 \sin \frac{3\pi}{2x} + \text{etc.} + b_1 \cos \frac{\pi}{2x} + b_3 \cos \frac{3\pi}{2x} + \text{etc.}$$

$$\text{and } e_3 = a_1 \sin \frac{3\pi}{2x} + a_3 \sin \frac{9\pi}{2x} + \text{etc.}$$

$$+ b_1 \cos \frac{3\pi}{2x} + b_3 \cos \frac{9\pi}{2x} + \text{etc.}$$

but since the expression

$$\sin \frac{m\pi}{2x} - \sin \frac{3m\pi}{2x} + \ldots + \sin \frac{(2x-1)m\pi}{2x}$$

will vanish unless $m = x$*, when the whole expression equals x, and also since

$$\cos \frac{m\pi}{2x} - \cos \frac{3m\pi}{2x} + \ldots + \cos \frac{(2x-1)m\pi}{2x} = 0$$

because m is necessarily an odd integer; then

$$(e_1 - e_3 + \ldots + e_{2x-1}) = a_x x$$

$$\text{or, } a_x = \frac{1}{x}(e_1 - e_3 + \ldots + e_{2x-1})$$

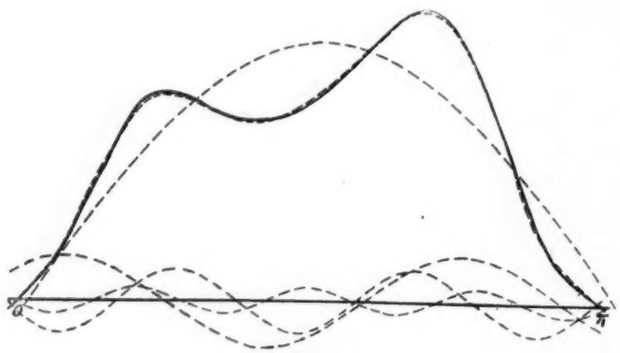


FIGURE 2.

Equation (6) is not so evident. The expression

$$-\sin \frac{2m\pi}{2x} + \sin \frac{6m\pi}{2x} + \text{etc.}$$

must vanish, since $2m$ can not equal x; but on the other hand

$$-\cos \frac{2m\pi}{2x} + \cos \frac{6m\pi}{2x} - \ldots + \cos \frac{2(2x-2)m\pi}{2x}$$

will reduce to 1 except when $m = x$ when it becomes equal to $(x-1)$. Therefore

$$(-e_2 + e_4 - \ldots + e_{2x-2}) = -b_1 - b_3 - \ldots + (x-1)\,b_x$$

Since $a_1 \sin \phi$, $a_3 \sin 3\phi$, etc., are in phase with the plotted curve, and $b_1 \cos \phi$, $b_3 \cos 3\phi$, etc., lag on lead by 90°, it follows

$$b_1 + b_3 + \ldots + b_\infty = 0$$

$$\therefore\ (-e_2 + e_4 \ldots + e_{2x-2}) = x\,b_x$$

The resultant of $a_x \sin x\phi$ and $b_x \cos x\phi$ is a single sine curve of the same frequency and may be expressed

$$c_x \sin (x\phi + \Theta_x)$$

$$\text{where } c_x = \sqrt{a_x^2 + b_x^2}$$

and $\Theta_x = \tan^{-1} \frac{b_x}{a_x}$, is the angular difference between the harmonic and the principle curve. If b_x is (—) then tangent Θ_x is negative and the harmonic lags; if b_x is (+) the harmonic leads the principle. If a_x is (—) the angle of lag or lead is over 90°.

The curve in Figure 1 gives

$a_1 = 105.2$	$b_1 = -7.4$
$a_3 = 14.4$	$b_3 = 12.2$
$a_5 = -13.1$	$b_5 = -3.3$
$a_7 = -5.1$	$b_7 = -1.5$

*Equations (5) and (6) would be correct to the accuracy of the plotted curve if only harmonics of the first degree existed; but with harmonics present that are multiples of the lower harmonics, these equations are not correct. For $\frac{1}{3}(e_1 - e_3 + e_5)$ is not a_3 but $a_3 - a_9 + a_{15}$, etc. By finding the higher harmonics first this error may be eliminated. However, the percentage of error introduced by neglecting all above the seventh is often less than the error of the observed curve.

from which can be derived the complete equation

$$e = 105.5 \sin (\phi - 4°) + 18.9 \sin (3\phi + 40°) + 13.5 \sin (5\phi - 166°) + 5.3 \sin (7\phi - 164°) \quad (7)$$

Figure 2 is the same curve, showing the derived components. The dotted curve is calculated from (7) and agrees very closely with the plotted curve.

The presence of any harmonics increases the inductance of the line, but this is only worthy of consideration when the line is comparatively long. They also decrease the efficiency of polyphase induction motors. In two-phase circuits the third, if too great, may increase the motor slip and decrease the torque because it sets up a rotating field of frequency, $3n$, in opposition to the fundamental. If $c_1 \sin \phi$ and $c_1' \sin \phi$ are the fundamental waves of the leading and following phases respectively, $c_1' \sin 3\phi$ lags behind $c_3 \sin 3\phi$ by $3 \times \frac{\pi}{2}$ or leads by $\frac{\pi}{2}$, which is the exact reverse relation compared with the fundamentals. The field of the fifth rotates in the same direction as the fundamental; the seventh opposing, etc.

In three-phase currents, the thirds, differing in phase by $3 \times \frac{2\pi}{3}$ or 360°, are merely added to one another, and cause no rotating field. Beyond adding to iron and copper losses, they are not detrimental. The fifth, however, like the third in two-phase circuits, sets up a reverse field, increasing the slip, and decreasing the torque, of the motor.

Physics

FUNDAMENTAL IDEAS OF ALTERNATING CURRENTS.*

BY PROF. DUGALD C. JACKSON.

A DEEPLY rooted belief seems to have been cultivated in the minds of many that the phenomena connected respectively with the flow of continuous electric currents and of alternating electric currents are as widely separated as are the extremes of the diameter of eternity. This popular idea, however, is totally erroneous and the principles which relate to the flow of direct and alternating currents and which are applied to the design and construction of machines and circuits are one and the same. In this paper will be given a straightforward statement of the elementary electric and magnetic principles which relate to the flow of alternating currents. To the majority of those interested in the subject, the paper contains no new information; those to whom it is new will perhaps not be uninterested. I have even been careful in choosing analogies to select as far as possible those heretofore used in electrical literature, and have then utilized them in the most straightforward manner for illustrating electrical phenomena.

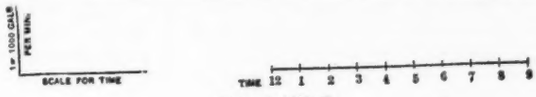
When Oersted, in 1820, made known his signal discovery that an electric current exerts a magnetic influence in the space around it, the foundation was begun for our knowledge of the laws of the flow of alternating currents. Within a dozen or fifteen years thereafter, much knowledge of the magnetic effect of the electric current has been thrashed out experimentally by men like Ampere, Arago, Faraday and Henry. And the last two laid the finishing stone on the foundation by searching out and making known the laws of electromagnetic induction.

The apparent flow of electric current may be likened to the flow of a fluid, and it may be either continuous, pulsating or alternating.

1. The first is analogous to the flow of an unbranched river through its channel, in a season of uniform flow. The water flows continuously onward without pause or hesitation. The velocity of the stream is affected by the character of the banks and the contour of the country traversed; but the onward motion of the volume of water never ceases and the

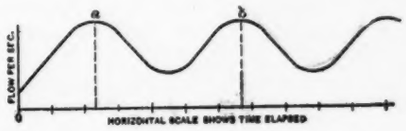
*Paper read at the Convention of the Northwestern Electrical Association.

quantity of water flowing past any cross-section of the channel is always the same, though its width, depth and velocity may change with the character of the channel. We may represent the flow in a graphical manner in this way: Suppose distances measured on the vertical from a zero or horizontal line represent the quantity of water which each minute flows past some point along the river. Then a vertical line one inch long, we will say (Fig 1), means that 1,000 gallons of water pass the point in every minute. Now suppose a number of measurements are made through twenty-four hours and the clock times when the measurements taken are recorded. Then we have a number of vertical lines each one inch long for every 1,000 gallons per minute to represent the amount of water flowing at each instant through the day and night. We can now extend our chart, and divide our horizontal line of zero quantity into parts each representing one hour, as in Fig. 2. And at each of the clock times set down we may erect the vertical which has a length corresponding to the quantity of water flowing. This river is continuous in its flow and all the verticals are therefore of equal height, as in Fig. 3.



FIGS. 1 AND 2.

FLOW PER MIN.
12 1 2 3 4 5 6 7 8 9 O'CLOCK
LINE SHOWING QUANTITY OF WATER FLOWING AT ANY TIME DURING 24 HRS.
FLOW PER MIN.
12 1 2 3 4 5 6 7 8 9 O'CLOCK



FIGS. 3, 4 AND 5.

We may take our observations of flow as frequently as we choose and erect the corresponding verticals at the points corresponding to the clock times of the observations. Finally, by drawing a line through the tops of the verticals we have a chart which shows by the vertical height of this line the rate of flow at any time during the twenty-four hours (Fig. 4).

In the case that we are considering—that of continuous flow—the line drawn through the ends of the verticals is a horizontal line, that is, the chart shows that the flow of water is uniform.

2. A *pulsating* current may be likened to the flow of arterial blood. With each heart beat the blood rushes forward and then slackens in velocity and then again rushes forward as the heart beats again. The chart, which shows the quantity of blood flowing through the artery at each instant, is in this case composed of a wavy line which never crosses the zero line, as is shown in figure 5.

The horizontal scale now, instead of being made in hours, may be more conveniently made in seconds or in fractions of a second, since the blood pulsations come many times per minute, and the vertical scale may be made to represent a flow in fractions of a fluid ounce per second instead of gallons per minute, because of the limited amount of blood that flows in an artery. The vertical height of the wavy line in the chart, above the horizontal scale line, still shows the amount of blood flowing at each instant corresponding to the times read on the horizontal scale. The *frequency* of the heart beats is the number of pulsations made per minute, which is not far from 70 in the average human adult, and the duration or *period* of the pulsations is therefore not far from one-seventieth of a minute. The period is represented on the chart by the time elapsed between two like points, as the two points of greatest flow, *a* and *b*.

3. Finally, the *alternating* current may be likened to the flow of water in a narrow tide way. As the tide rises the water rushes up the channel until near high tide, when the flow gradually ceases, turns, and then, with increasing flow, the water rushes down the channel until near low tide, when its outward flow gradually ceases, turns, and with increasing flow the water begins to rush up the channel again. The action is repeated again and again as the days pass by, the *period* of the complete action or cycle, *i. e.*, from low tide to high tide and back again is a little over twelve hours, and the *frequency* is therefore nearly two periods per day. We can represent this *alternating flow or current* also by a chart, as shown in Fig. 6.

Assuming the period to be exactly twelve hours (which is near enough for the analogy), and taking a day in which low tide occurs at 12 o'clock noon; then, at this time (12 o'clock noon) no flow is occurring; a little later the flow is up the channel as the tide rises, and the rate of flow increases for a time. This portion of the tidal period is represented by the portion of the curve between *a* and *b* in Fig. 6. It is to be borne in mind that the vertical height of the curve shows the amount of water flowing per minute at the instant considered (not the height of the water). The flow continues up the channel for a further length of time, but at a decreasing rate, until high tide is reached at 6 p. m. Then, for an instant, there is no flow of the water. In representing this, our curve, dropping down from *b*, crosses the line of zero flow at the point marked *c*, which corresponds to the instant of no flow at the time of high tide.

Half a tidal period has now been completed, the tide has reached its flood and begins to fall, and the flow therefore reverses and runs outwards. Since the flow inwards or up the channel is shown on the chart by a vertical distance above the line of zero flow, it is natural to represent the outward flow by a vertical distance below the line. After the turn of the tide the amount of flow increases for a time up to a minimum and then decreases as the low tide is approached. This is represented by the curve from *c* through *d* to *a'*. At the latter point, low tide has been reached and an entire cycle of the tide has been completed and is represented on the chart. The chart might be continued indefinitely, representing the cycles of successive periods if desired, as in Fig. 7.

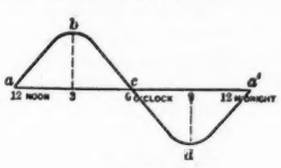


FIGURE 6.

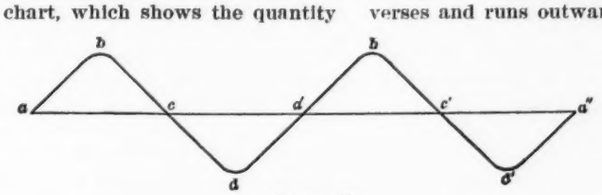


FIGURE 7.

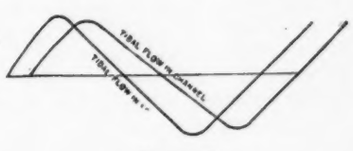


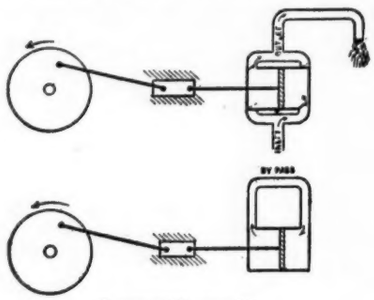
FIGURE 8.

It is well known that the character of the tidal flow is greatly affected by the character of the channel. For instance, in a narrow, crooked channel, the phase of the flow is retarded as one proceeds along its length, through the buffeting action of the banks. And the times of high and low tides, when the flow in the channel is zero, may not correspond with the times of similar tidal phases in some other channel or in the open

sea. In this case we may say that the tide in one channel differs in phase from that in the other, or that in the sea, and a chart may be drawn to represent the respective cycles of sea and channel tides at certain selected points, as in figure 8, in which the channel is shown to be *retarded or behind the tidal cycle of the sea.*

Alternating currents of electricity, flowing in branch circuits, may be at different phases, and they may be represented on a chart entirely similar to that of Figure 8. The currents are said to be out of phase, and may be said to be in advance or behind each other, depending upon which is looked upon as the datum for comparison; exactly, for instance, as we may,

FIGURE 9.



FIGURES 10 AND 11.

with equal propriety, and the same meaning, say either that the channel tide is behind the tide of the open sea, or that the tide of the open sea is in advance of the channel tide.

To recapitulate, the electric current may be continuous, pulsating, or alternating. The first is likened to a continuous flow of a river, the second to the pulsating flow of arterial blood, and the third to the alternating flow of water in a tide way. Continuous and pulsating currents, that is, currents which flow in one direction continuously, are often called "direct currents."

Another set of analogies to illustrate electrical currents and show relations still more clearly perhaps is as follows:

1. A continuous current is like a uniform current of water set in motion by means of a centrifugal pump operated at constant speed. (Fig. 9.)

2. A pulsating current is like a current of water set in motion by a piston pump. As the piston moves forward in the water cylinder, the water therein is forced to flow through the delivery pipe; when the piston reaches the end of its stroke the flow slackens or ceases, and as the piston returns on the stroke the flow again proceeds, as before, through the delivery pipe and slackens as the piston reaches its initial position. (Fig 10.) This is repeated as the stroke is repeated and the action causes a succession of impulses to the water with intervening pauses or slackening of the current.

3. An alternating current is like the current of water which would be set up in case the delivery and suction pipes of the piston pump were connected directly together and the valves removed. Now as the piston moves back and forth, the water flows unceasingly back and forth alternately from one end of the cylinder to the other as long as the pump is operated. (Figure 11.) This diagram (Figure 11) shows clearly that a complete cycle of flow is produced with each revolution of the pump driving shaft, that is, with each 360 degrees of angular motion of the shaft. We may, therefore, for the sake of convenience, divide the horizontal zero line or axis in our charts into 360 parts for each "period" of the flow, and call the parts "degrees," instead of fractions of time. This is illustrated in figure 12, which shows two alternating currents of different phases. We may speak of these as having 30 degrees difference of phase, or they are 30 degrees apart, since they cross the horizontal axis at points which are 30 divisions or *degrees* apart.

The alternating curves which are shown in the figures are all smooth curves, but actual waves of alternating current and pressure are usually more or less irregular in outline, and sometimes they are very irregular; but successive loops are normally similar. Two alternating current curves, the outlines of which were determined by experimental means, are shown in figures 16 and 17.

It is also a fact that alternating current curves do not have the same shape as waves of pressure which are applied to produce the currents, whenever any iron is magnetized by the current—which is almost always. The curve shown in figure 16 is the curve of current set up by a quite flat-topped, steep-sided pressure wave, while the curve of figure 17 was set up by a smooth pressure wave with a form quite like a sine wave. Changing the iron or other conditions of the circuit will produce changes in the forms of the current waves, though the pressure curves remain unchanged.

If a heavy block is suspended so that it is perfectly free to move, and then is struck a sharp blow, for an instant it offers a force which opposes the force of the blow almost as though the block were rigidly fastened. This opposing force is well known to be caused by the *inertia* of the block. Inertia sets up a force which tends to violently oppose any sudden change in the motion of a body, and when the suspended block is started swinging, it may strike a considerable blow upon its own account when met by an obstacle.

When an electromotive force is introduced into an electric circuit, the circuit by a kind of electromagnetic inertia, opposes the immediate flow of the current (very much as the inertia of the suspended block opposes the force of a blow before the block moves), and the rise of the current in the circuit is retarded. If the circuit is severed or broken while current is flowing, the electromagnetic inertia makes an effort to up-

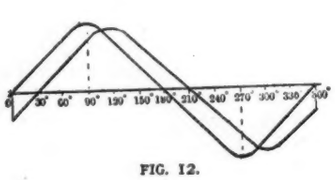


FIG. 12.

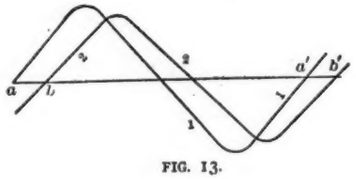


FIG. 13.

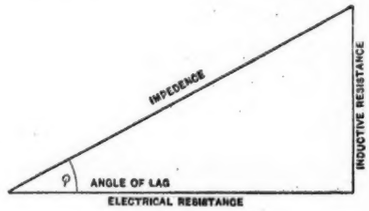


FIG. 14.

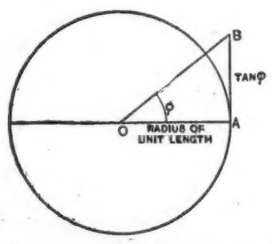


FIG. 15.

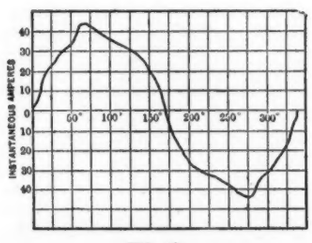


FIG. 16.

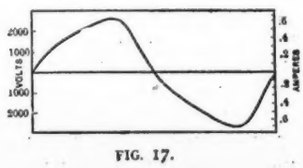


FIG. 17.

hold the current (as the swinging block is difficult to stop), and an electric spark appears as its evidence in the gap between the severed ends of the wire.

Faraday (whose name is almost a household word on account of his discoveries in natural philosophy, and especially in electricity and magnetism) was well acquainted with this retarding effect as early as 1835, and describes it in his "Experimental Researches." He says: "Returning to the phenomena in question, the first thought that arises in the mind is that the electricity circulates with something like momentum or inertia in the wire, and that thus a long wire produces effects at the instant the current is stopped which a short wire cannot produce. Such an explanation is, however, at once set aside by the fact that the same length of wire produces the effects in very different degrees, according as it is simply extended, or made into a helix, or forms the circuit of an electromagnet." He then shows that the apparent inertia is due to the magnetic effect of the current. For instance, he says: "Further investigation led me to perceive the inaccuracy of my first notions and ended in identifying these effects with the phenomena of induction which I had been fortunate enough to develop in the first series of the Experimental Researches."

Faraday further speaks of this as a *retardation* of the electric current in the circuit, and ascribes the effect to the "induction of the current on itself," or self-induction of the circuit. The phenomena of electromagnetic induction were studied about 1850 (fifteen years after Faraday's experiments) by Sir William Thomson (now Lord Kelvin), Helmholtz and other scientists, who brought to their aid the powerful resources of mathematics, and their work was canvassed and discussed by Maxwell in his book on "Electricity and Magnetism," who shows that the effect of self-induction is truly the result of *electromagnetic momentum or inertia.*

The retardation of the current by electromagnetic inertia was shown by Faraday to occur *when the current is changing in value,* and it therefore exercises a marked influence on the *ever changing alternating current.* Faraday showed that the value of the changing current was retarded or lagged behind the value which it might be expected to attain, and which a uniform current under the same conditions would attain. We therefore know that an alternating current will lag behind the phase of the alternating electromotive force which causes it to flow, if there is self-induction in the circuit. The amount of the lag depends upon the electromagnetic character of the circuit. Thus, a straight wire causes less *retardation* or lag than the same wire wound in a helix, because the helix increases the magnetic effect. Inserting an iron core in the helix may increase the retardation enormously, since the presence of the iron again increases the magnetic effect. Faraday said: "If an electromagnet be employed the effect will be still more highly exalted," as compared with the effect of the plain coil or helix of wire.

Faraday's experiments were mostly carried on with varying or pulsating currents. but later investigators took hold of alternating currents and much attention was given to the laws of flow of alternating currents at the time alternators became known.

We all have at our fingers' ends the well-known ratio generally called Ohm's law, in which it is asserted that a continuous current is equal to the electrical pressure upon a circuit divided by the electrical resistance of that circuit. This so-called law is nothing more than a special statement of a condition which may be recognized as universally applicable to the phenomena of nature. The general statement may be put thus: The result of an effort is equal to that effort divided by the opposing resistance. Thus, for instance, if we stretch an elastic material the amount of stretch will depend upon the ratio of the pull to the elastic resistance of the material; if we try to push a heavy block along the floor the velocity of the block will depend upon the ratio of the force exerted to the frictional resistance opposing the motion; and so we could go on indefinitely illustrating the general applicability in nature of this statement that the result is dependent upon the ratio: effort divided by resistance.

We then have for the flow of continuous currents the rule that current flowing ("result") is equal to pressure ("effort") divided by the opposition to the current flow ("resistance"); but in the case of continuous currents there is no opposition to the flow of the current except electrical resistance (that is, the resistance which is determined by the nature, temperature and dimensions of the conductor), whence we have Ohm's law for the flow of continuous currents.

The fundamental law of the flow of alternating currents follows directly from what has gone before. The alternating current flowing in a circuit is equal to the pressure divided by the opposition to the flow of the current. In this case the opposition is made up of two parts, one the electrical resistance spoken of above, and the other the opposition due to electromagnetic inertia. The latter effect is a sort of inductive resistance and is commonly called *reactance.* The total opposition to the flow of alternating currents which is made up of these two components (resistance and reactance) is called *impedance,* and it is numerically equal to the square root of the sum of the squares of the electrical resistance and the inductive resistance or reactance. These three factors, therefore, bear the same relation to each other as the three sides of a right angle triangle in which the hypothenuse has a length equal to the impedance and the base and altitude are respectively equal to the electrical resistance and inductive resistance (Fig. 14).

The fundamental laws of flow of alternating currents may be briefly stated thus:

1. The current flowing in a circuit is equal to the alternating electromotive force divided by a quantity called the *impedance,* or apparent resistance. This impedance is equal to the square root of the sum of the square of the electrical resistance and the square of the inductive resistance.

2. The alternating current lags behind the alternating electromotive force applied to a circuit containing inductive resistance by a certain angle (as illustrated in Fig. 12). The trigonometrical tangent of this angle is equal to the inductive resistance of the circuit divided by its electrical resistance.

The electrical resistance of a wire composing a circuit depends, as is well known, upon the material and temperature of the wire, its length and its cross section; and it is not affected by the flow of current, provided the temperature is not affected thereby. The inductive resistance is dependent upon the self-induction (*i. e.*, the electromagnetic condition of the wire) and the frequency of the alternating current. The effect of the self-induction is to retard the rise and fall of the current so that it attains its maximum later than the maximum of the alternating pressure which sets it up; and it also increases the apparent resistance to the flow of the alternating current in the circuit. Thus, if the curve 1 in Fig. 13 is taken to represent the alternating current which flows in a circuit supposed to contain no self-induction, then curve 2 can be taken to represent the current which flows when there is self-induction. Curve 2 is retarded with respect to curve 1 and reaches a smaller maximum value.

These laws can be put into very simple mathematical form:

$$\text{Alternating current} = \frac{\text{Alternating electromotive force}}{\sqrt{(\text{electrical resistance})^2 + (\text{inductive resistance})^2}}$$

$$\text{Tangent of angle of lag} = \frac{\text{Inductive resistance}}{\text{Electrical resistance}}$$

It is usual, for brevity, to use the letter I* to represent electric current, the letter E to represent electomotive force,

*In this age of enlightenment it seems to be as senseless to use the letter I as an abbreviation for current as it does for a woman to wear earrings—both being legacies of by-gone customs. The consistent and rational abbreviation for current is C.—THE EDITOR.

the letter R to represent electrical resistance, and the Greek letter ϕ to represent the angle of lag. Inductive resistance is equal to a constant (equal to twice 3.1416+ times the frequency of the alternating current times the self-induction coefficient for the circuit). The letter L is usually used to represent the latter coefficient, the letter f is often used to represent the frequency of the current, and the constant, 3.1416+, which enters into a large number of physical equations, is usually represented by the Greek letter π. Inductive resistance is therefore represented by the collection of letters, $2\pi fL$.

Using these symbols, we have our laws of flow represented in the manner that they would usually appear in text-books or published articles. Or,

$$I = \frac{E}{\sqrt{R^2 + (2\pi fL)^2}}$$

$$\tan \phi = \frac{2\pi fL}{R}$$

In Figure 13 the distance from a to b measured in degrees (it being remembered that each degree is represented by a length equal one three hundred and sixtieth part of the distance $a\,a^1$ representing the length of one period) is the angle of lag ϕ.

I will use numerical examples to illustrate the way in which the laws apply. Let us assume that we have a circuit with four-tenths of a unit, or ohm, of resistance, and one-thousandth of a unit of self-induction. What will be the angle of lag when the frequency is sixty periods per second (this is a common commercial frequency)? The formula representing the current lag becomes

$$\tan \phi = \frac{2\pi fL}{R} = \frac{2 \times 3.1416 \times 60 \times .001}{.4} = .943-$$

and the angle corresponding to a tangent of .943— is nearly 43½ degrees, which is the value of Φ.

Now suppose that we increase the number of turns of the wire so as to increase the inductive resistance to double the value assumed above and carefully avoid changing any other feature. Then tan Φ becomes equal to twice its former value 1.886— and Φ is a little over 65 degrees. Exactly the same result would have been brought about by using larger wire in the circuit, so that the electrical resistance was reduced to one-half its former value without changing anything else, or by altering both the inductive resistance and electrical resistance, so that the ratio $\frac{2\pi fL}{R}$ is doubled.

It is clear, then, that the alternating current in a circuit may be given any desired lag or retardation, at least up to nearly 90 degrees, by merely adjusting the electrical condition of the circuit so as to properly fix the ratio of inductive resistance to electrical resistance. This may be done by changing the character of the circuits or by introducing into the circuits what are called variable resistance coils, or variable self-induction coils, or it may be done by changing the frequency of the alternating current flowing in the circuit.

When the electric current flows through a circuit the power that is absorbed in the circuit at every instant of time is equal to the product of the pressure at that particular instant and the current flowing at the same instant. In direct current circuits the pressure and current are virtually constant; consequently the power is continually the same and without changes from instant to instant, however long the current continues to flow, provided the indications of voltmeter and ammeter remain unchanged. The indications of these instruments therefore show the average current flowing and the average pressure applied to a circuit, so that their product gives the average power, and we say that power is equal to current times pressure, or, what comes to the same thing, power is equal to current squared times resistance.

The same fundamental principle applies in the alternating current circuit. That is, the power expended at every instant is equal to the corresponding product of the instantaneous current and the instantaneous pressure. Our amperemeter and voltmeter, however, do not indicate these instantaneous values, and it is only when the circuit contains no self-induction to cause a lag of current through the effects of electromagnetic inertia that power is equal to the product of the alternating current and the alternating pressure indicated by the instruments. When the current is displaced with respect to pressure, that is, it is caused, for instance, to have a lag on account of the effect of electromagnetic inertia, the average of the instantaneous values of the power throughout any complete cycle in the alternating current circuit is always less than the product of the current and pressure read from the amperemeter and voltmeter. This product of amperes times volts is generally called the apparent power or volt-amperes in the circuit, and the ratio of the true power to the volt-amperes is called the *power factor*. When the waves of current and pressure are exact sinusoids (sine curves), this power factor is numerically equal to the trigonometrical cosine of the angle by which the current lags behind the pressure. But the condition of exact sinusoids for both current and pressure can be said to be never met with in practice, and, indeed, it is seldom that either of the curves are exact sinusoids, though pressure waves are not uncommonly made up of curves that approximate quite closely to that form.

We must therefore consider the power factor as simply the ratio between the true power and volt-amperes in the alternating current circuit, and we may say that it is equal to the cosine of the apparent angle of lag in the circuit.

Power may be measured by a wattmeter. This is an instrument which indicates the average of the product of instantaneous currents and pressures in the alternating current circuit. In the case of indicating wattmeters, we have a simple pointer which plays over a scale in a manner similar to the arrangement shown by amperemeters and voltmeters. In the case of recording wattmeters the armature of the instrument is usually caused to rotate continuously when power is being absorbed by the circuit to which it is attached, and a record is made of its rate of rotation or of the number of its rotations. The rate of rotation in this case is proportional to the average of the products of instantaneous currents and pressures. In the indicating wattmeter the rotary effort is balanced by means of springs and the deflection of the needle is thereby caused to be proportional to the average of the product of instantaneous currents and pressures.

The power factor of a single phase circuit may always be found by measuring the power by a wattmeter and the volt amperes by means of an amperemeter and a voltmeter and taking the ratio of watts to volt-amperes.

ELECTRICAL ENERGY IN MICROSCOPIC VALUES.

ADDENBROOKE estimates* that with the usual type of telephone transmitter, the impressed voltage on the circuit when speaking into the transmitter in the ordinary way, is between one-quarter and one-half of a volt. This is the average voltage produced on the secondary of the transmitter coil by singing into the transmitter a note of about the same loudness and pitch as the average voice.

On the other hand, Caldwell,† who has detailed some interesting experiments on the determination of the energy of telephone currents under conditions approaching those of every-day practice, holds that the maximum instantaneous value of the energy of an ordinary telephone current probably reaches one-quarter of a watt or more. The strongest energy which Caldwell succeeded in producing with a carbon transmitter under conditions favorable for producing powerful currents, reached a value of 2.25 watts, or 0.003 horsepower.

The Electrician, Vol. XLIV, page 516, No. 15.

†*Electrical Review*, (N. Y.), Vol. XXXVI, page 8, January 3, 1900.

Insignificant indeed though the energy value of a telephone current may be, yet it is enormous in comparison with the energy which actuates the coherer of an ordinary wireless telegraph instrument. Abbott* states that the amount of energy received by a coherer is approximately one fifty-millionth of a watt, and that the efficiency of transmission from the oscillator to the coherer is one five hundred millionth of one per cent. "While such low efficiency is abhorrent to the commercial instincts of the calculating engineer," says Mr. Abbott, "one stands amazed at the delicacy of the apparatus that will so swiftly and unerringly detect such minute quantities of energy as are represented by the amount of a millionth of a watt. We see, therefore, that while the coherer is marvelously sensitive its efficiency is also marvelously low."

Traction

CONNECTIONS OF THE JUNGFRAU LOCOMOTIVE.

A COMMUNICATION concerning the Jungfrau polyphase locomotive has been published by E. K. Scott in a recent issue of a valued English contemporary† from which the accompanying diagram of circuit connections is reproduced. Singularly, Mr. Scott gives no detailed explanation of the diagram but dismisses it with the scant comment that it is "surely simplicity itself." While no one will contend that it possesses any especial complication, it is certain that American readers held a decided preference for the writings of an author who will not give them a pig-in-clover puzzle when a quick conception of existing circumstances is wanted.

The figure shows that two legs of the three-phase current are taken into the locomotive through two trolley poles with their

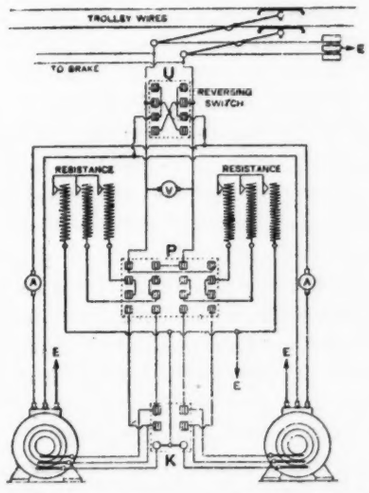


FIGURE 1.—CIRCUIT CONNECTIONS OF THE JUNGFRAU LOCOMOTIVE.

respective sliding shoes — two trolley wires being used, of course— and the third leg of the generator being grounded. The car wiring is also grounded at points *E*. *U* is the reversing switch, by means of which the direction of rotation of the motors is controlled through reversing two of the three-phase-leads; *V* is a voltmeter; *A A* are ammeters; *P* is a quadruple-pole, double-throw switch by means of which the variable resistances shown may be thrown into the rotor windings of the respective motors as will be done when the switch is in the lower position; or, when the switch is in the upper position, the variable resistances will be cut into the stator circuits for braking purposes. The necessity of some such arrangement will be understood when it is known that the Jungfrau locomotives operate on grades as high as 25 per cent. The device *K* is evidently a switch which, when open, throws the rotor leads on to the lower clips of the quadruple switch *P*, and which, when closed, short circuits the rotor windings.

Since the above was written there has appeared a valuable article, also by E. K. Scott,* which gives a really admirable description of the entire system of the Jungfrau three-phase electric railway. From it it appears that the use of the three-phase system was determined upon after having received the estimates of the engineers, Messrs. Wust-Kunz, of Seebach, and Thormann, of the Oerlikon staff, who reported that the great distances covered would necessitate transmission by alternating currents at high tension and transformation down by static transformers and rotaries to continuous current, or by static transformers only, using three-phase motors on the locomotive. These engineers found that in the first case, where the three-phase currents are transformed into continuous currents, the cost of installation would approximate £38,000 whereas by the exclusive employment of three-phase currents the cost would be only £25,000 The latter method was therefore adopted. In September, 1898, the first section of the system was opened, while the tunnel has now been completed to the Eiger station, which is 3,950 metres† from Scheidegg, where the road begins.

When the line is completed it will contain twelve transformer stations, the last one being for operating the elevator ascending to Jungfrau peak. The total length of the line will be 12,100 metres. When the system is finished, there will be two power stations—one of 2,300 horsepower on the White Lutschine at Lauterbrunnen, which is now in operation, and the other (the Burglanen station) of 2.600 horsepower on the Black Lutschine near Grindelwald. Rieter turbines of the twin Girard type and six in number, are used, the effective head being 35.5 metres. The generators are of the Oerlikon inductor type, delivering three-phase current at 7,000 volts and 28 periods per second. Two exciters each delivering 150 amperes at 120 volts are used, these being direct driven from separate turbines in conformity with the best European practice which has shown that in hydraulic stations, where the load is very variable, it is better to have separately driven exciters. The generator circuits are in star connection, the substation transformers being in delta. All high tension work is placed in a special room at the back of the switchboard and the high tension fuses consist of wires run in porcelain tubes that are open at the ends and lined with fireclay. The total cost of the generating station, including buildings. dam, pipe line, generating plant, etc., is estimated to be about $55.00 per horsepower, which, considering the situation, is a low figure.

The transmission line will be about 22 kilometres (about 13½ miles) in length, and will consist of three hard drawn copper wires each 7.5 millimetres (about No. 1, B. & S. gauge) in diameter. These are mounted on triple petticoat poreclain insulators 4½ inches in diameter by 7 inches high. the poles being of fir, 10 metres high, and impregnated with sulphate of copper. When the system is finished, triple conductor concentric cables will carry the high tension current in all tunnels, these cables to be laid in sand and inclosed in an earthenware trough. Horned-type lightning arresters are placed at all points, presumably on the pole line, where injury could be sustained. The trolley wires are calculated for a drop of 12 per cent, and consist of two copper wires, each 9 millimetres (about No. 00 B. & S. gauge) in diameter, supported by span wires from wooden poles. which also support the telephone wires. The trolley wires are 4 metres above the rails, and suspended at from 18 to 25 metre intervals. When exactly between two stations, as shown in figure 2, which indicates 1,000 metres from the nearest transformer, there is a drop of 12 per cent in the voltage. In this position the locomotive is

(Continued on page 72.)

*Transactions American Institute of Electrical Engineers, Vol. XVI, page 674, November 22, 1899.

†*The Electrician*, Vol. XLIV, page 585, February 16, 1900.

Engineering Magazine, Vol. XIX, page 33.

†One metre = 39.37 inches.

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EDITORIAL.

ENGINEERING ASSOCIATIONS IN THE WEST.

In the material advancements to be derived from fraternization are found the cornerstones upon which have been built the innumerable associations in scientific, engineering and commercial fields, all mighty institutions from which naught but good results. The savants in mining, mechanics and electricity have formed institutions for the advancement of their professions the civilized world over. Some are purely of local import, others achieve national prominence, while often the spirit for yet further fraternization becomes so irresistible that all barriers of politics, creeds, and even the tongues of Babel, are swept away as chaff that international congresses may be held for the good of man, of civilization and of science. Of such was the Congress of Religion held in Chicago in 1893, as well as the various engineering congresses also held during the World's Fair, and of such is to be the World's Congress of Electricians to be held next August during the Paris Exposition. The pages of the engineering press teem with knowledge derived from the papers, or transactions, of the American institutes of electrical, mechanical or mining engineers; with those taken from the conventions of the National Electric Light Association, the American Street Railway Association, the Pacific Coast Electric Transmission Association, and a host of lesser organizations whose memberships are largely confined within the lines of a single state or city. The spirit is universal and all-pervading with civilized mankind from the humblest of the laboring class, who form unions, on up the scale of prosperity or influence through the trades, professions and corporations, to at last the governments of the world, which form alliances. Though complications doubly confounded, and even then thrice confounded, be the lot of some affiliations, yet in science and engineering associations are universally found all that is necessary to perfect the ideal. Their goal is the gold of knowledge, the reaching of which is now achieved by ungenerous means; and knowledge is the key to the universe. And, let it be asked, does not the tree of knowledge mature soonest when fertilized with intelligent and enlightened reasoning?

It will be conceded then, that the organization and faithful administration of engineering societies is, as stated, productive of naught but the greatest possible advancement to the branches of industries represented. It is true that local conditions are always paramount factors in an engineering sense, and for this reason one turns to the oil fields of, say, Pennsylvania, for the ripest experience in the matter of oil development and treatment; to the Lake Superior and Montana regions for the engineering detail of copper mining; to Colorado for silver mining; and to California and South Africa for gold mining, just as the lover of music makes Germany his culture-ground or the art student makes Paris his Mecca. Similarly, the American engineer looks to the Eastern states when in quest of the highest attainments in steam engineering; to Lynn, or rather Schenectady, for knowledge concerning the heaviest direct current or street railway practices; to Newark for the best electrical instruments; to Pittsfield for the most advanced types of induction generators; or to Pittsburg for the greatest experience in the development of alternating apparatus. In brief, and speaking of the electrical situation mainly, the entire East is the acknowledged home of the theory, the design, the manufacture, and, almost wholly, the practical development of American electrical apparatus. The honors are its inheritance, and from it they shall probably never be wrested. There its engineering associations may discuss theories, and devise designs, and work themselves into innocuous somnolency over abtruse problems in differential calculus, all to their own hearts' content, and the West, in wishing them God-speed, will say "every man to his liking." More than this, the manufacturers of the East will long continue to build electrical machinery and apparatus of a quality that none others can begin to approach, and they will, as at present, refuse to send them from the shops until they have successfully passed every conceivable electrical, mechanical and practical test. Clearly, the theoretical and practical development of the electrical industry in America is due to the truly herculean efforts of the East, and there the engineering societies will ever lead in all that bespeaks the highest attainment of the art.

Despite all this, the West has most emphatically earned a prominent place in the molding of industrial developments; California alone is at once the birthplace and nursery in America for gold mining practice, the cable railway and high potential electric power transmission. Is not this enough to establish the truth of the contention made? If the West can lead the world in selected lines of engineering development—as it does—are not its engineers in a position to make their Pacific Coast association a power in the engineering world—as they should?

To revert to the electrical situation: There are two

avenues by means of which western electrical interests may reach the goal of most cordial fraternization with their eastern brethern, and the time for action in this direction will have come at a very early date, if it has not already arrived. One is through close affiliation with the American Institute of Electrical Engineers, which is very attractive; and the other is through the Pacific Coast Electric Transmission Association, which has long since established its invaluable intrinsic worth. With the Institute, all depends upon its Board of Managers; will it cease to view the prayers of the western members with indifference? With the Association, all that can be, is; for whatever else remains to be done can only be accomplished by the individual exertions of the engineers and managers themselves. It is very true that the Technical Society of the Pacific Coast extends a welcoming hand that is by no means to be refused without the fullest considerations; but then one must bear in mind that the electrical business has reached such an enormous magnitude in the West, and that its applications permeate into almost every root and branch of industry so deeply that its importance unquestionably warrants the maintenance of a society that shall be exclusively devoted to its many needs.

The several efforts which have heretofore been made to establish local meetings of the American Institute of Electrical Engineers in San Francisco proved to be signal failures, partially because they were spasmodic, and partially because of the unnecessary fewness of Institute members residing on the Coast, but more particularly because the Board of Managers of the Institute did not understand, and apparently made no particular or serious effort to understand, the local conditions that must govern the gatherings of a body of men located some three thousand miles away. In passing, the sincere desire—nay, hope—may be expressed that these words record only past and deeply buried relations rather than the slightest intimation of present conditions. At present, however, the electrical fraternity of the West is, in the main, not convinced that its general interests will be best subserved by the consummation of the much-to-be-desired scheme of holding formal local meetings. Local meetings of an informal nature will probably be generally preferred; but even so, such discussions as will be held will then lack the stamp of authenticity. These and many other points of like nature will arise and must be settled before definite action is determined upon. A preliminary and informal meeting of local Institute members is much to be desired and will probably be called at an early day, but every chance for success or failure depends upon the appointment which shall be made to the local honorary secretaryship of the Institute, made vacant by the recent removal of Dr. Perrine from California. That this appointment shall be determined upon only after the fullest inquiries have been made into western conditions, is the uppermost desire of all those who have the best interests of the electrical community of the West at heart. In the meantime the fate of the Institute on the Pacific Coast for years, if not decades, to come, is in the balance—and may it never be found wanting.

There are some who contend that the Pacific Coast Electric Transmission Association should properly be relegated into the category of a commercial organization—that is, that its deliberations should be confined to matters of commercial rather than technical import. In substantiation of this it is averred that such organizations as the American Street Railway Association and the National Electric Light Association are drifting away from technical detail and are now mainly considering commercial questions and policies. Technical matters, it is contended, have no place in such "essentially commercial bodies" as the Street Railway, the National Electric Light, and the Transmission Associations, but instead, they properly belong to the American Institute of Electrical Engineers where (the inference is patent) they will only receive intelligent handling.

These columns have no sympathy with such views, nor do we believe that they will be otherwise than repugnant to the electrical communities of the country. Unquestionably the Institute is the most able to discuss the higher and theoretical sides of the electrical business; and while the street railway and electric light conventions may be drifting in the direction indicated, it must be remembered that they represent industries which have practically passed the stage of evolution and have settled down to that domain wherein expansion or extension means mainly a matter of larger units. But it is not so with the Transmission Association, nor with the engineers whose fields of work are within its scope. Here conditions exist that are paralleled in no other section of the country, for the breadth of electrical transmission practice of the West is to that of the East as the depth of the mines of California is to that of the mines of Pennsylvania. The East will design and build the plant machinery, but the West, with its doubled voltages and tripled distances, with its novel applications and heroic undertakings, has the broad practical experience along the line of hard working detail that is invaluable to engineers the world over. Where may this dearly-bought experience be most worthily bestowed—to the Institute or to the Transmission Association?

That is the question which the events of the present year will undoubledly decide.

POLYPHASE TRACTION IN A NUTSHELL.

Apropos of the subject of induction motors for railway work, it is of importance to note the opinion of Dr. Louis Bell* who believes that considerable misapprehension has arisen in confusing the commercial induction motor for stationary work with the machine which would be designed for railway work, and states that it is as if one solemnly set forth the fact that the average shunt-wound multipolar motor could not be conveniently applied to a street car, whereas we know that the modern railway motor is a highly specialized machine, the result of ten years of persistent modification for that purpose. On the

*Electrical World and Engineer, Vol. XXXV, page 371.

other hand, the commercial induction motor is designed for ordinary service at the usual frequencies. The very small clearance often found is simply the cheapest way of getting a good power factor with a moderate speed motor of cheap construction as regards the windings. With a properly designed machine from 30 cycles or thereabouts there is not a bit of trouble in getting a power factor of 90, or very near it, while retaining ample clearance for the purpose, and that in a motor of approximately the same commercial efficiency, speed and weight per horsepower as the usual railway motor. Under these conditions the wattless-current bugaboo slips out of sight, particularly if one considers the ease which the induction motor lends itself to fairly high voltages. The increase of current demand with such motors is at least no greater than the increase of energy demand caused by the losses in rotary converters. Speed regulation of induction motors may be obtained on precisely the same terms as in ordinary railway motors with rheostatic control.

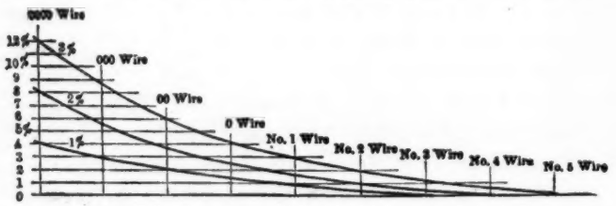
To Dr. Bell's mind, the only difficulties in the way of using induction motors are the double trolley and the extra cost of non-standard apparatus, and both of these are of moderate importance only, in the long interurban work for which an alternating distribution is most desirable. No one type of apparatus is best for all purposes, of course, and he thinks that induction motors assuredly have a useful field in certain classes of railway work.

Distribution

INDUCTANCE DROP IN INTERIOR WIRING.*

BY CECIL P. POOLE.

IN most interior wiring the inductance drop may be ignored, the only cases in which its recognition is desirable being those requiring the use of wires larger than No. 2, B. & S. gage. This is shown by the accompanying diagram, which is a set of curves giving the relation between the energy drop of wires three inches



apart, and the increase in drop due to inductance at 133 cycles. The ordinates are standard wire sizes and the abscissæ are increments of increase in per cent. of the energy drop, which is represented by the curves.

Thus, if the load on a No. 0000 feeder is such as to give an energy drop of 2 per cent., the drop will be increased 8 per cent. of the energy value, making the actual drop 2.16 per cent. The diagram shows that there is no increase in the drop of No. 3 wire when the energy drop is 1 per cent.; none in No. 4 wire when the energy drop is 2 per cent., and none for No. 5 wire when the energy drop is 3 per cent. The wires are assumed to be three inches apart, and carrying a non-inductive load, which is a common condition of interior wiring on ceilings and in mouldings.

Of course, a power factor changes the relations tremendously. Assuming a fixed electromotive force at the load, a frequency of 133 and wires three inches apart, a pair of No. 2 wires showing an energy drop of 2 per cent. with a load power factor of unity shows an actual drop of only 2.02 per cent. But if the load have a power factor of .90 with exactly the same current value as before, the actual drop goes up to 2.25 per cent. And if the load be changed to one of the same value in real watts, with a power factor of .90, the drop goes up to nearly 3 per cent.

**Electrical World and Engineer*, Vol. XXXV, page 285—abstract.

Historical

ELECTRICAL PIONEERS OF THE PACIFIC COAST.—I.*

WILLIAM LUNDBERG.

THE electrical development of the Pacific Coast owes much to Wm. Lundberg, who, in addition to being the first manufacturing electrician to cast his fortune with San Francisco at a time when the telegraph was almost a thing of wonderful mystery, was easily the pioneer worker in this branch of science on the Pacific Slope. Along the Union Pacific, and from San Francisco to New Westminster, there are, in many places, guarded as precious relics, relays, keys, sounders and even registers that bear the imprint of Mr. Lundberg, who made them when he was the purveyor for such things to, first, the State Telegraph Company, and, after its absorption, to its successor, the Western Union Telegraph Company, under James Gamble, as superintendent. This was in the early days of electrical progress, when Frank Jaynes, John I. Sabin, and some other electrical notables of to-day were expert operators, and when Mr. Vandenburgh was assistant to Mr. Gamble in the superintendency of the railroad telegraph.

WILLIAM LUNDBERG.

In almost every instance of the early applications of electricity on the Pacific Coast Mr. Lundberg bore a hand. In addition to the telegraph work he was the engineer who arranged the electrical details of the famous explosion of Blossom Rock, in the Bay of San Francisco, and in the electrical equipment of which he had full charge; he planned and inaugurated the electric fire alarm systems in San Francisco and Portland, Oregon, making many of the signal boxes with his own hands, and the first hotel annunciators to be turned out in San Francisco were made by Mr. Lundberg from his own original designs for the Horton House at San Diego and the Arlington Hotel at Santa Barbara.

Mr. Lundberg was born in the city of Copenhagen, Denmark, on September 6th, 1836, of one of the best families of that ancient kingdom. A student from his earliest youth, he, at fourteen years of age, spoke, beside his native tongue, German, French and English fluently. He had a turn for the mechanical arts, and was apprenticed to a manufacturer of mathematical and philosophical instruments. His uncle, P. Faber, the director general of the Royal Telegraph, instructed him in the system of the electrical transmission of signals as then known, and in other electrical matters as well. After the close of his apprenticeship Mr. Lundberg traveled through

*This serial, which will appear in parts from time to time, is published to give deserved recognition to those whose early labors in the electrical field on the Pacific Coast entitle them to the distinction of pioneership in the establishment of an industry that is, or promises to soon be, second to none in promoting the industrial development and commercial attainment of the Far West. Every effort toward securing accuracy in dates, places and names is being exerted; personal experiences, anecdotes and recollections will be introduced wherever pertinent, and, in brief, a serial that shall be replete with interest may be anticipated.

Previous references to electrical pioneers of the Pacific Coast have been published as follows:

Monroe Greenwood, the JOURNAL, Vol. III, page 69, October, 1896.
Orion Brooks, *ibid*, Vol. IX, page 51, March, 1900.

Germany, France and England, gaining a practical knowledge of the profession to which he was to devote his life. In 1855 he came to New York, and at once found employment with Charles T. and J. N. Chester, the leading manufacturing electricians of the country at that time, and during this period he became acquainted with Professor S. F. B. Morse, the inventor of the telegraph, whom he assisted in some experiments. Mr. Lundberg also worked on the original inventions of Elias Howe —presumably his sewing machine inventions.

In 1861 Mr. Lundberg was lieutenant of a company of telegraphers which offered its services to the government, but these being refused, Mr. Lundberg accepted a call from the California State Telegraph Company to take charge of its manufacturing department, to fulfill which engagement he reached San Francisco toward the end of 1861. Two years later he started into business for himself, and his instruments went all over the coast and a distance eastward. On April 24th, 1870, he conducted the electrical part of the blowing up of Blossom Rock, which obstructed the main channel of San Francisco harbor, with success, and in 1871 he sold out his business to carry out a special mission to Japan in connection with the establishment of a telegraph plant in that empire. This was a crucial era in Mr. Lundberg's career, as, indeed, it was in the development of the electrical business, and the trying experiences then endured are best told by excerpts from a diary which Mr. Lundberg kept. In regard to his trip to Japan, Mr. Lundberg says in his journal: "When the Japanese Embassadors arrived in San Francisco I was introduced to them by Colonel Von Schmidt through the American Minister De Long. I became very well acquainted with the Minister of Public Works in Japan, Governor Ito, who offered me the position of General Superintendent of Telegraph of the Empire, which I accepted under an agreement for three years at $5,000 per annum. Day after day he promised to have the papers ready, and at last when I saw him off for the East at the railroad office in Oakland, he told me that he had neglected to write out my papers, but that it was all right, that he had written to Japan, and all I had to do was to leave on the next steamer, and on my arrival there I would be received and accepted by the Japanese Government. On the 4th of February, 1872, I left on the steamer 'America' for the golden shores of Japan. We arrived safely in the harbor of Yokohama on March the 5th. As the Government, of course, had received news of our arrival we expected to hear from them in some shape, but we heard nothing. On the 9th of March, after having heard nothing from either the Government or General Williams, I started for Yeddo, where I presented myself to General Williams, who kindly took me in hand and introduced me to several of the ministers, but they had no news for me or in regard to my situation. I told them my exact position in regard to my engagement by Governor Ito. They told me they did not doubt that it was all right, but asked me to kindly wait until they could hear from Ito. I was also introduced to E. George, Chief of the Telegraph Department, who is quite a cosmopolitan, but still is down on Americans on general principles. He was very polite, but close, and would not tell me anything in regard to telegraphing in Japan, in consequence, I suppose, of an article which appeared in one of the papers in Yokohama, naming me as his successor. This article brought forth quite a controversy among the different papers, giving the Americans 'fits' in all directions. On March 14th I departed again for Yokohama. When General Williams and the Assistant Minister of Finance left for Europe shortly after, the latter presented me with a very beautiful sword of the kind they commit hari kari with. It is an old and splendid weapon and was used by one of the minister's predecessors, who committed suicide.

"On the 25th of March the steamer Japan arrived from San Francisco, but the Government received no news in regard to me. The ministers now told me to await Governor Ito's return with the embassy, which they were sure would be within a year. They said they could give me a position in the telegraph department, but I would have had the whole force against me; they also told me that they would have no objection to my returning to San Francisco. I was really at a loss what to do. There is no chance for a white mechanic to save a dollar. I thought I would try what I could do in my electrical line of business, and sought private individuals for the purpose of putting up burglar alarms, but business being dull, no one wanted to 'risk any money.' I had my room in the hotel fitted up with alarm bells, so that by opening a door, window or any of the drawers in my bureau it would give an alarm. I also fitted up my electrical machine in such a way that you could hardly touch a thing in the room without receiving a severe electrical shock. I then invited several parties of Japanese, as well as Europeans, to come and take a 'Hi Kin.' They were all very much pleased, but being an American prevented me from receiving any orders. Talk about being astonished—why you ought to have seen the Japanese on that day! I will never forget it as long as I live, and at last they got so scared that they wouldn't touch me for anything. The hotel lies close by the water. I had a ten-pound can of powder inclosed in a strong beer barrel, and had it fixed so with stones that I sunk it in the water at a depth of about eight feet. I had my wires connected and had my machine on the balcony of the hotel. After having explained the whole thing to all, I got one of the high-toned Japs to give the machine a few turns. The explosion that followed astonished them all. The Japs stood perfectly still, with staring eyes and open mouth, rooted to the spot. They first looked at me, and then at the machine, and then at the water, then they commenced shaking their heads as if to make sure that they were still on their shoulders. Then finding that everything was all right, they commenced calling me all the great names they could think of, and thanking me for the great pleasure they had experienced, at the same time almost kissing their very toes before me. I never laughed so much in my life as I did on that occasion. The next day I called on the United States Consul, who said he could do nothing for me. All my dreams of my brilliant situation and what I was going to do for Japan were shattered, and I suffered frightfully at the idea of being in a strange land with not a single friend to turn to."

The diary then narrates how he found a young German suicide at the point of death, who had also been misled into going to Japan by Ito, but lacked the nerve to stand the strain, after having taken part in several serious collisions with the Japanese who were hunting foreigners with murderous intent.

The journal continues: "The telegraph in Japan does not amount to much. The lines are very poorly built and the instruments they use are at least ten years behind the age. The officers consist of one chief superintendent and six assistant superintendents, the latter receiving a salary of $250 a month. These men, upon my word, would not receive more than thirty dollars a month in America, and the whole length of line there is only about fifty miles. It is swindle. During my short stay of fifty days in Japan I traveled and saw more than many a person residing there for years, but it was not until I had fully made up my mind to return to dear San Francisco that a blessed rest came over me, and I felt at ease once more. The steamer 'Japan' was to sail from Yokohama on April 23rd, so after paying another visit to Yeddo and seeing no signs of promise I returned to Yokohama and took the steamer. We arrived safely in San Francisco on May 17th. When I reached Oakland I found the house in which I had lived burned down, and no one knew what had become of my people. I expected to get about three thousand dollars from a friend to whom I had intrusted some stock, but he had absconded a few days before my arrival. This news entirely unnerved me, and I suffered keenly and my entire system gave way, and I became sick, but I fought it down and became another man. Business being very slack, I could not find a

single job in town for quite a while, when one offered at eighteen dollars a week, which I took, and gave up shortly after for one that paid twenty."

After his return from Japan he lived in San Francisco until 1875, leaving thence in November for Portland, Oregon, where he was in business—a portion of the time with Julius Dilg—and also acting as Superintendent of Fire Alarm until April, 18, 1883, when he and his wife made a tour of Europe, visiting his old home. On their return to this country Mr. Lundberg established himself in business in Los Angeles, and was ever active in promoting electrical matters, both by manufacturing and by lecturing before scientific societies up to the day of his death, June 15th, 1898.

Personally, Mr. Lundberg was a cultured, polished gentleman of wide, general and scientific knowledge, and ever ready to assist those who were engaged in scientific study. He was a man of high principle and devotion to business, and a tribute to his personal courage, in the latter characteristic, was that published in the *Alta-Californian* on April 24th, 1870, when Blossom Rock was blown up. The article said: "Mr. William Lundberg, who has had charge of the electrical department, worked through Thursday, Friday and up to 2 A. M. on Saturday, in the terribly dangerous task of making the wire connections between the various receptacles of powder in this death-charged marine cavern. A young electrician went over on Friday to help him, but his nerve failed him, and came ashore again, leaving the other to do the best he could. Lundberg did well and bravely, and Colonel Von Schmidt is loud in his praises of him." The first attempt at explosion was a failure, and Mr. Lundberg and Colonel Von Schmidt, at the peril of their lives, went upon the rock and discovered a broken wire which, being spliced, the blast was set off without further trouble.

Mr. Lundberg's career in San Francisco filled in the gap when electrical matters were of a primitive sort, and he personally exercised a great influence in the early advancement of the applications of electricity in his chosen fields of labor. He was an honored thirty-second degree Mason, also a Knight of Honor, and was well beloved by his brothers for his faithful and untiring labors among them.

Personal

NORMAN ROWE, whose resignation from the electrical engineership of the Westinghouse Electric and Manufacturing Company's Pacific Coast office, and whose departure for the City of Mexico in acceptance of the chief engineership of the San Il DeFonzo transmission was noted in the last issue of the JOURNAL, was born in Oswego, N. Y., in 1867, where he attended the public schools and did some electrical work of a general nature before going to college. He graduated from Cornell University in 1893, having taken the electrical engineering course, and among his classmates was Kempster B. Miller,* best known from his authorship of the invaluable work on "American Telephone Practice." Mr. Rowe and Mr. Miller both graduated with the degree of mechanical engineer with mention of the fact that particular attention was paid to electricity, for Cornell does not give the degree of electrical engineering. After graduation, Mr. Rowe entered the employ of the Westinghouse Electric and Manufacturing Company at its Pittsburg works, where, after having a short general experience, he was given a responsible position in the testing department. There he remained for four years during the time when nearly all the development work on induction motors and rotary converters was being done, and for about two years of this period Mr. Rowe had charge of this particular class of testing. When induction motors and rotary converters were first placed upon the market by the Westinghouse company, Mr. Rowe was put on the road for a short time, principally on "trouble jobs;" in February, 1898, he was sent to Mexico by the Westinghouse company to install the Riveria Grande transmission, on the completion of which, in July last, he was ordered to San Francisco to the position he has just vacated.

NORMAN ROWE.

*A review of Mr. Miller's chief engineering writing, as well as a brief biography, appears on page 28 of the present volume of the JOURNAL.

Mr. Rowe's departure for a foreign country on March 19th last was the occasion of genuine regret among the electrical and engineering fraternities of San Francisco, whatever were their affiliations, and in wishing him unbounded success and prosperity they unite in assuring their engineering friends across the Mexican border that in Mr. Rowe will be found one who is well worthy of every confidence and esteem, whether in an electrical engineering or in a personal capacity.

A. C. BUNKER, of the engineering staff of the Stanley Electric Manufacturing Company, has taken full charge of the electrical engineering work of the Standard Electric Company of California, making his headquarters in the offices of the Standard company, Crocker Building, San Francisco.

HENRY HINE, general manager of the Stanley Electric Manufacturing Company of Pittsfield, Mass., spent a few days in San Francisco during the first of March.

CONNECTIONS OF THE JUNGFRAU LOCOMOTIVE.

(Continued from page 67.)

obtaining half the current it uses from each of the stations shown, and the voltmeter registers the lowest voltage obtainable. As the locomotive leaves the central position, the volts rise gradually in proportion to the distance of the locomotive from the transformers, and by this means the motorneer can tell almost exactly the distance his locomotive is

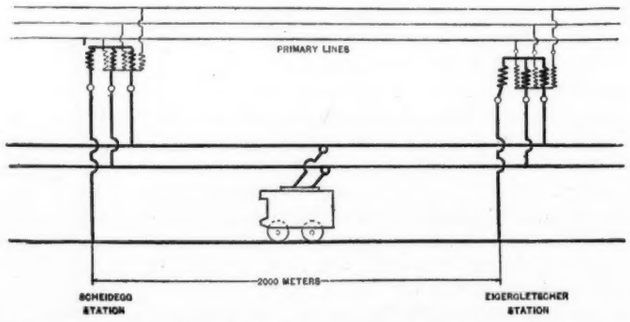


FIGURE 2.—SUB-STATION AND TROLLEY CONNECTIONS, JUNGFRAU LOCOMOTIVE.

from the nearest station. The speed of every locomotive is almost constant, and signals are given to the stations on starting. The first two locomotives put into use were equipped electrically by Brown, Boveri & Company. Each of the two motors therein develop 150 horsepower at 760 revolutions per minute, and actuates a rack wheel through a double reduction gear disposed symmetrically on either side. There is one set of rotor resistance coils for the two motors. Current is taken from the overhead wires by four trolley poles, each carrying a sliding shoe.

Recently the Oerlikon Company has furnished three other locomotives for the Jungfrau railway which are of greater power than those first installed, each giving 200 horsepower at 550 revolutions per minute, the speed being reduced by two trains of gearing—1 to 4¼ and 1 to 2, respectively. These are the motors whose diagram of circuit connection is shown in figure 1. The truck has four axles, the two inner ones being driving axles, which carry the rack pinions, these pinions each having 22 aluminum bronze teeth. Unlike the Brown-

Boveri motors, the Oerlikon motors have a resistance for each motor and a ¾ horsepower fan motor supplies air for cooling the resistance coils. The author, in describing the connections of the Oerlikon locomotive (figure 1), states that *K* is a three-pole switch, one pole of which is connected to earth. *U* is the reversing switch, and *P* is the switch for altering the resistance connections. On starting the locomotive up hill, *K* is open, and the full resistance is in each rotor circuit to give the necessary torque. *U* and *P* are switched over to the up-hill position, that is on to the upper clips with switch *U* and on to the lower clips with switch *P*, and as the locomotive speeds up the resistance is gradually cut out. On the steepest gradients the locomotive starts of its own accord as soon as the brakes are released, but on low gradients current is necessary to start the locomotive because of the rack friction. In this case *K* is open and the full resistance is thrown into each rotor circuit. *U* is then reversed for running down hill and *P* remains unchanged. When the locomotive has started *K* is closed, the resistance is switched in and *P* is thrown over to the upper clips for down-hill running. By following the connections it will be seen that the resistance is now in parallel with the stator circuit.

The reason for this arrangement is the small amount of traffic at present on the line. Suppose, for example, that only one locomotive is going up and another is coming down, and that the latter has reached its highest permissible speed and is supplying current to the one going up. Now, if the ascending locomotive stops at a station, or if, for any other reason, the load on the descending locomotive is suddenly removed, it may cause a dangerous speed—so much so that the generating plant at the power-house may be "motored round." In the first locomotives built this contingency was guarded against by having a resistance in the main line at Lauterbrunnen, so that when a locomotive was about to start it was necessary to signal to the power-house to have the resistance temporarily switched in. When there is considerable traffic these inequalities of load on the generating plant will cancel out and the ideal method in which those motors which are descending will supply power to work those that are ascending, will be employed.

The last station of the railway will be about 66 metres below the summit of Jungfrau, whence will be run an elevator to its very peak. In this elevator a three-phase motor is carried on the car itself and turns two other pinions working into two racks fixed along the walls of the elevator shaft. There are also two other toothed racks in which will be engaged toothed pinions working the automatic speed regulators. All the machinery is placed under the floor of the elevator car, and great speed, together with absolute safety, is obtained.

Literature.

POWER TRANSMITTED BY ELECTRICITY, by Philip Atkinson, A. M., Ph. D. 12-mo., cloth, 241 pages, and 94 illustrations; second edition, revised and enlarged. Published by D. Van Nostrand Company, New York, 1899. Price, $2.00.

This is a book which emphasizes strongly the necessity for the coinage of a new word in electro-technical phraseology. No one will gainsay the fact that the delivery of direct current motor service from an isolated plant in a single building, or that the operation of an ordinary electric railway system, do not constitute examples of the electrical transmission of power. This use of the phrase in each case is technically and literally correct, but nevertheless, when an engineer speaks of an electric power transmission he conveys the idea that material distance is to be traversed by the transmission, and that, in brief, he refers to a full-fledged electrical transmission from a distant source of cheap power, and probably at high voltage. Ordinarily the operation of direct current, low tension motors at short distances from the generators are not considered in electrical parlance as constituting a "transmission," even though the operation of a street railway system is involved. There should be another name for such classes of electrical service, for the two fields are widely separated. The first edition of this book appeared under the title "The Electric Transformation of Power," concerning which the author states that while the title "properly expressed the fact of the transformation of power into electric energy, and the transformation of this energy into power after transmission, it was too suggestive of technical intricacy," which the author was anxious to avoid. Far better had he retained the old title, for the new one is positively misleading. He should know that there is a great demand for literature on the subject of long distance, high potential electric power transmissions, that the few works which have been brought out on that line are in greatest demand, and that, in view of the fact that the present book can lay no claim to being a treatise of electric power transmission in the ordinary acceptance of the term, the title of the second edition will bring at least disappointment to most of those who perchance may buy it, in that they will fail to find a realization of their hopes by a perusal of the matter between its covers.

The scope of the work has been perhaps sufficiently indicated by the foregoing. It gives definitions of electrical terms and then discusses the "principles of the electric motor" in chapter II without giving the slightest intimation of the existence of any class of electric motor other than those of direct current types, with the single exception of making the rather unwarranted declaration that "alternating current motors are still in the experimental stage of development." The chapter on "Stationary motors," however, gives a semi-popular description of the Westinghouse "Type C induction motor which, it appears therefrom, "ranges in size from 1 to 100 horsepower," yet the book bears the date of 1899. We learn on page 75 that rotary "transformers" must be "started and raised to the proper degree of speed by a small auxiliary alternating current motor." as though rotaries were never started from the direct current side, as is almost invariably done where two or more rotaries are used. The section on electric railways will be considered as excellent by many. The cuts of the Fort Wayne self-starting single phase motors are pretty good, and its circuit connections form an impressive diagram. Then, again, the book brings up tender reminiscences of the middle '80s, or thereabouts, by reproducing cuts of the good old C. & C. series fan motor that we used to run with bichromate batteries—and what not? But after all, the book is worthy of a ready sale among those who possess, or unconsciously aspire to possess, a little knowledge concerning matters electrical.

The Engineering Times. A monthly engineering magazine bearing the watchword "Popular and Practical." Edited by Benjamin H. Morgan and published by P. S. King & Son, Orchard House, Westminster, London. Annual subscription, 9 shillings.

Among the recently appearing engineering publications of merit is *The Engineering Times*, an English illustrated magazine that is strongly suggestive of our own *Cassier's*, both in size and style, though clearly it has not yet reached the eminent degree of quality and tone in either subject matter or typographical appearance that was long since attained by that most popular American magazine. Still, this criticism is not offered disparagingly, for while comparisons are innately odious, there are times, such as in the present instance, when they become complimentary. When a new magazine that has not yet passed the first year of its existence becomes of sufficient worth to bring itself up so that its standard of comparison can only be found in such a magazine as *Cassier's*, then the mere mention of the fact is a compliment indeed.

Its most valuable number thus far issued is probably that devoted to the special subject of "Aerial Wire Ropeways, Their Development, Use and Construction," which appeared

during May last, and a copy of which, in reprinted form, has just reached the reviewer's table. This number will soon prove to be invaluable when in the hands of one who is interested in the aerial ropeways that, by the way, are fast forging to the front as a means of transport, especially in rugged or mountainous regions.

TRADE LITERATURE.*

"The Ericsson Series." A trade periodical issued in parts and containing telephone information of value. Circulation presumably gratuitous. *Ericsson Telephone Co,*, 296 Broadway, New York.

"Bullock Calendars." These are highly artistic calendars by months, issued monthly. They are 3½ x 6 inches in size and are really the daintiest advertising calenders for the desk yet issued. *Bullock Electric Manufacturing Company*, Cincinnati, O.

Fort Wayne Bulletins. No. 1006, illustrated description of elegant designs of "'Wood' Arc Lamp Suspension Cut-outs;" No. 1007, a twelve-page description of new styles of the new and novel features embodied in the "'Wood' New Focusing Series Arc Lamp." *Fort Wayne Electric Works (Inc.)*, Fort Wayne, Ind.

"Light and Power Installations for Residences and Hotels." This is unquestionably the most artistically prepared trade brochure that has yet been received. The finest tinted paper with ragged edges, profuse and original illustrations of some of the finest country estates around New York City, and a choice blending of colors, combine to present an advertising publication in a luxurious setting. It describes a number of installations. *Westinghouse, Church, Kerr & Co.*

Westinghouse Bulletins. No. 192-C, "Belt-Driven Polyphase Generators;" No. 222-A, "Direct-Connected Railway Generators;" No. 1000, "Type 'C' Polyphase Induction Motors for Constant Speed;" No. 1001, "Belt-Driven Railway Generators;" No. 1002, "Generators and Rotary Converters for Electrolytic Work;" No. 1003, "Direct Current Engine-Type Generators for 125-volt Service;" No. 1004, "Direct Current Engine-Type Generators for 250-volt Service;" No. 1005, "Belted Type Multipolar Generators and Motors for Direct Current Lighting and Power;" No: 1006, "Lightning Arresters for A. C. and D. C. Circuits;" No. 1007, "Direct Current Series Arc Lighting Generators;" No. 1008, "Belt-Driven Single-phase Alternators for 1100 and 2200 volts, 16,000 a. p. m.;" No. 1009, "Belt-Driven Polyphase Alternators, 220, 440, 1100 and 2200 volts, 7200 a. p. m." *Westinghouse Elec. and Mfg. Co.*

"Electric Elevators." This is without doubt the most artistic brochure-catalogue which the Pacific Coast has yet produced. Its half-tones demonstrate the high state that the art of photo-engraving has reached in San Francisco, and its typographical appearance is of the best. The booklet illustrates a few of the many buildings on the Pacific Coast that have been equipped with direct-current electric elevators built by the Electrical Engineering Company, as well as describing the elevator mechanisms themselves by means of relief engravings. The list of elevators in use is a formidable one and goes far toward proving the correctness of the assertion of the manufacturers that their elevators are in all but universal use on the Pacific Coast. *Electrical Engineering Company*, San Francisco.

General Electric Bulletins. No. 4201 (superseding in part No. 4109), on "Alternating Current Switchboard Panels for Circuits of 2500 volts or less." Switches, fuses, instruments, synchronizers, arresters, etc., are discussed. No. 4204, "Cabinet Panels," illustrates most recent practices for the control and protection of house and building circuits. Price lists are included. No. 4205, "Thomson Polyphase Recording Wattmeters," pertaining to a new G. E. wattmeter for use on three-phase, two-phase or the monocyclic system, in either balanced or unbalanced loads, giving reading therefor on a single dial. No. 4207, "Three-way Sockets and Three-way Snap Switches," is a bulletin announcing that a three-point lamp socket to work in conjunction with a three-way snap switch, has been brought out. No. 4208, "Potential Transformers," is descriptive of instrument transformers, having primaries from 1100 to 11,000 volts, and of various periodicities from 25 to 125 cycles. No. 4209 (superseding No. 4175), "Induction Motors," a popular description of forms K and L of the G. E. induction motor, with references to a starting compensator with oil break switch for large motors, and the effect of induction motors upon the regulation of the system. Dimensional and mechanical date are included. *General Electric Company.*

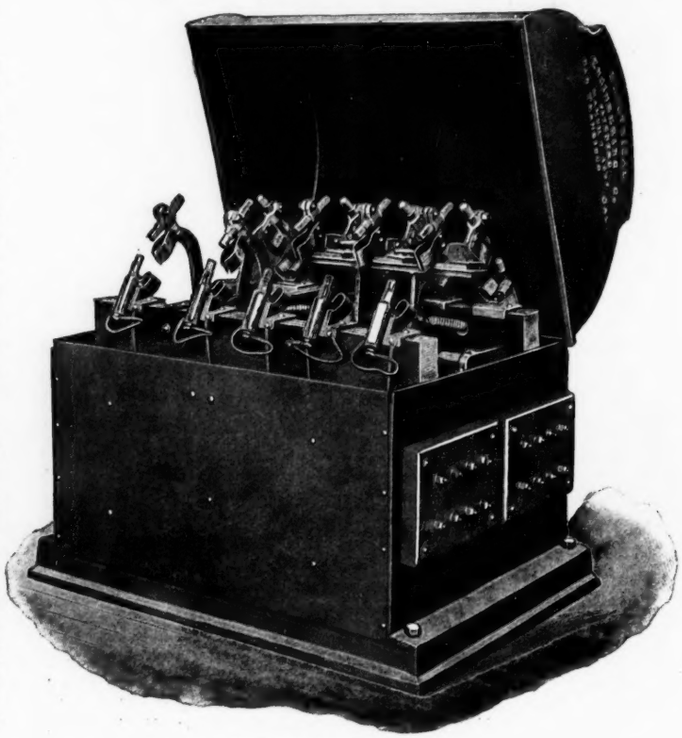
*Catalogues mentioned in this department will be mailed gratuitously on application to the concerns publishing them. When writing, mention THE JOURNAL OF ELECTRICITY, POWER AND GAS. Where addresses are not given, they may be found through reference to the Advertisers' Index on page v.

Industrial

In responding to advertisements in this publication kindly mention "The Journal of Electricity, Power and Gas."

ELECTRICAL ENGINEERING COMPANY'S ELEVATORS.

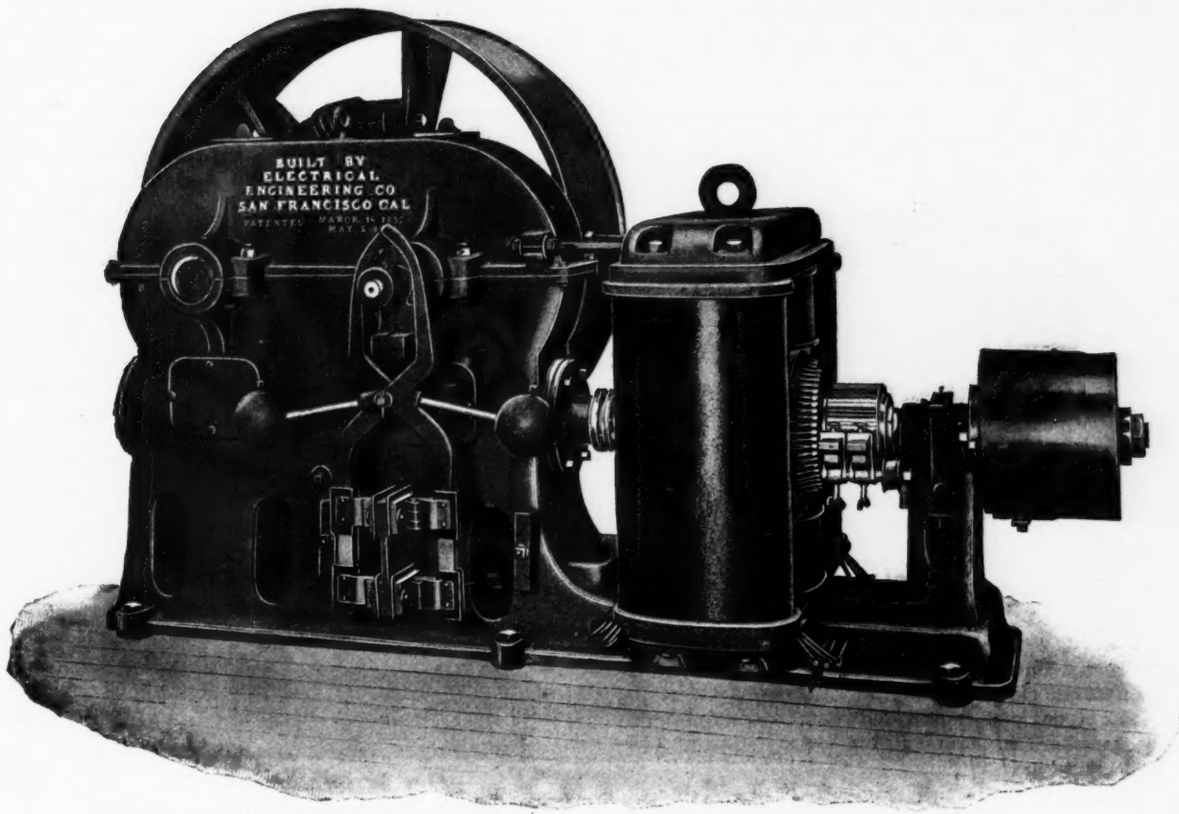
DIRECT current direct connected electric elevators for passenger and freight service are distinctive on the Pacific Coast as constituting essentially the only class of electric machinery that the West is not dependent upon the East to manufacture and supply. In fact the great majority of electric elevators in use in San Francisco and, though to a lesser extent, in California as well. are those of



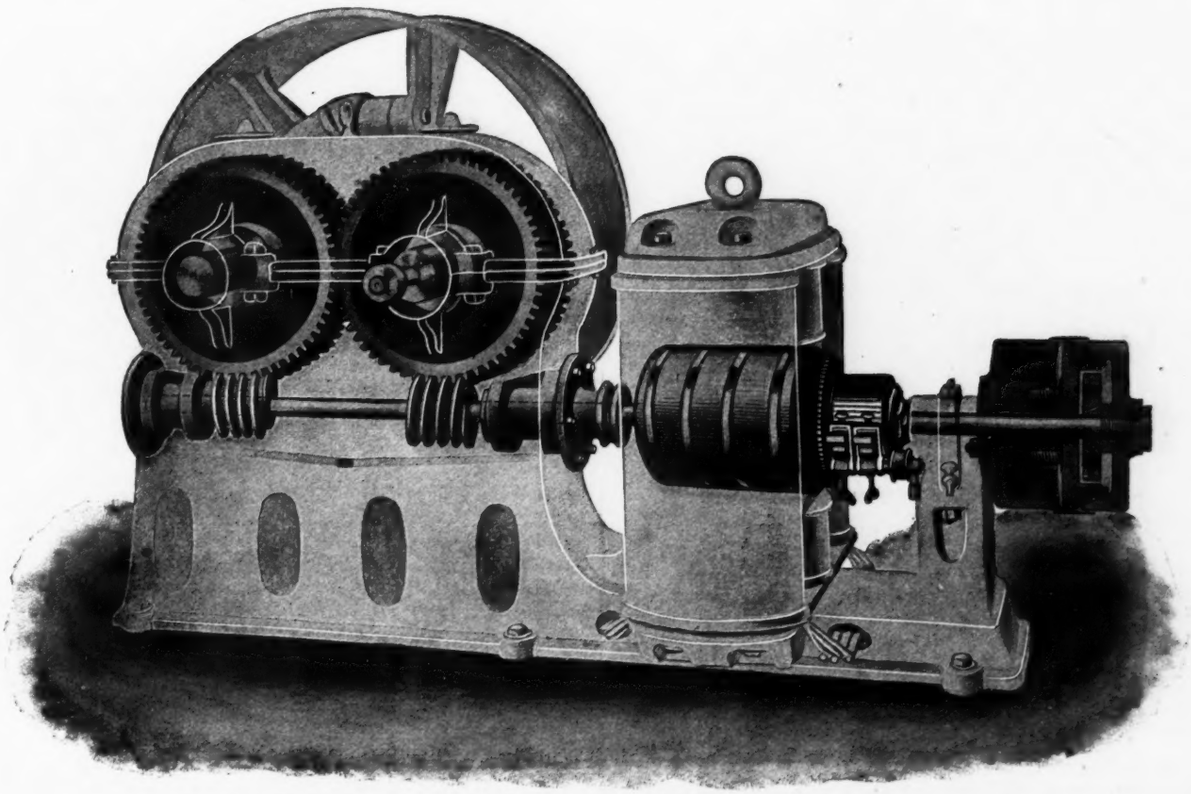
ELECTRICAL CONTROLLER.

the type manufactured by the Electrical Engineering Company of San Francisco, which it is the province of this article to describe.

Electrically, the distinctive features of the Electrical Engineering Company's elevator equipment are found in the fields of the motors, in the novelty of the electro-magnetic brake release and in the controller. The equipment for passenger service is made in two forms, namely, the double worm and the single worm types, both of which are illustrated in the accompanying engravings, to which is added a "transparent" view of the double worm equipment for illustrating the gear workings and the details of the brake. The fields are distinctive in that they carry, in addition to the ordinary field wind-



FIFTEEN-HORSEPOWER ELECTRIC ELEVATOR EQUIPMENT, DOUBLE WORM TYPE.



FIFTEEN-HORSEPOWER ELEVATOR—TRANSPARENT VIEW OF ELECTRICAL EQUIPMENT.

ings for a compound-wound motor, a separate and distinct set of windings for resistance or rheostatic purposes, these latter being cut in as a starting resistance upon starting up the motor. An intensely over-saturated field is thus obtained without the expenditure of additional energy beyond that ordinarily lost in the starting box, and as a result the motor

OPERATING LEVER.

has an enormous starting torque—which is a very desirable qualification in an elevator motor. The armature is of the Gramme ring type, and indeed the motor is without distinguishing peculiarities beyond the fact that it is emphatically of the "bull" type.

The brake is automatic in every respect, as it is actuated either by the manipulation of the controller, by cessation of the current from any cause or by reaching the limits of car travel. It overhangs on the armature end of the motor shaft and exerts its breaking effort by the pressure of a beveled wooden collar against the inner surface of the headplate, which is also beveled. This pressure is from spiral springs that are normally opened so as to lock the brake, but when the controller throws potential upon the equipment, the cast iron core forming the section of the brake head nearest the armature is magnetized by the coil within it, the plate carrying the wooden collar is attracted to the magnet, and the brake is released. Obviously, any interruption to the circuit controlling this magnet actuates the brake, and its action is positive.

The controller is manipulated from the operating lever, which is placed in the cage. Briefly described, the controller consists of a series of solonoids actuating, by lever movements, respective clip switches that are fitted with carbon brakes. These switches merely cut in or out the desired motor connections, giving various speeds to the cage as indicated by the operating lever.

Mechanically, the equipment represents the highest advancement in shop practice and its efficiency of operation is so very high that it gives fullest explanation for the fact that in San Francisco there are more than double the number of Electrical Engineering Company's elevators in use than of any other manufacture. The equipments are installed in California by Wm. L. Holman, San Francisco; in Washington and Oregon by Northwest Fixture Company, Seattle; and in British Columbia by Geo. C. Hinton & Co., Victoria. B. C.

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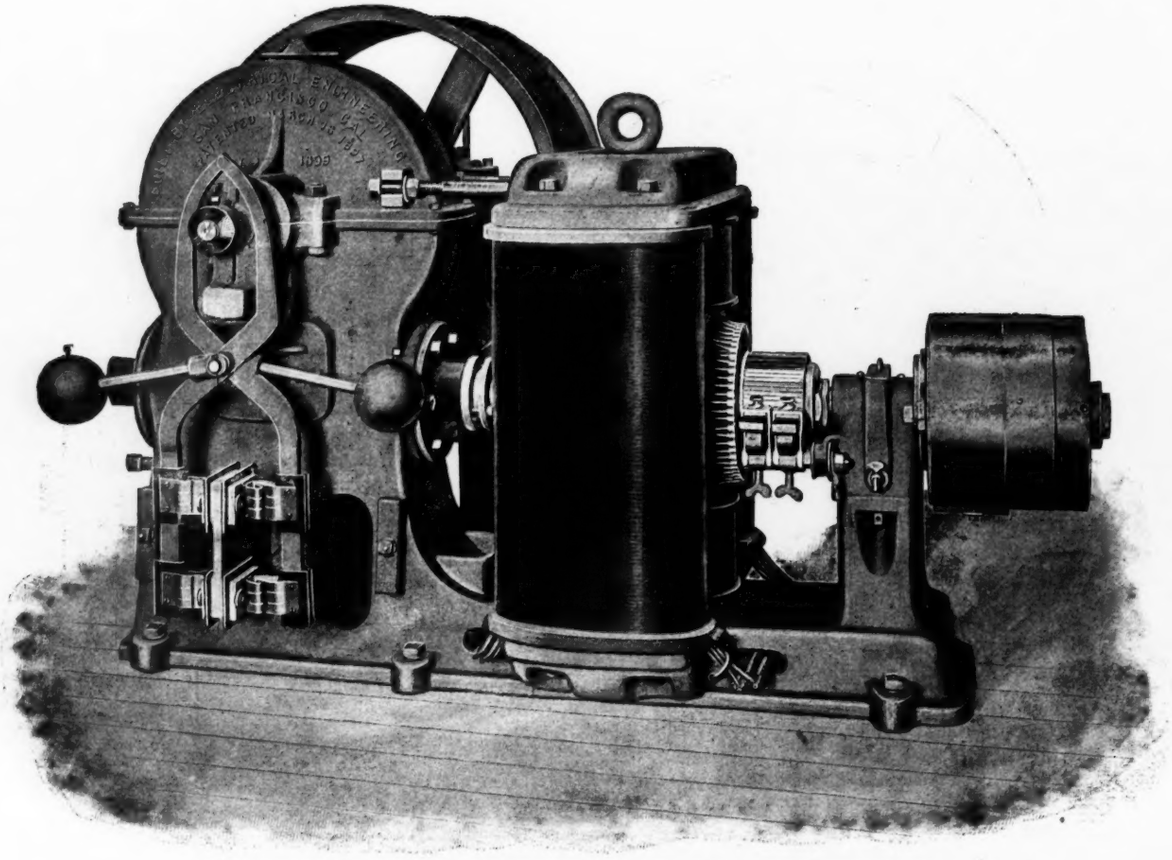

TEN HORSEPOWER ELECTRIC ELEVATOR EQUIPMENT SINGLE WORM TYPE.